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A case study of Kanban implementation within the Pharmaceutical Supply Chain

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Abstract

The paper explores the implementation of the kanban system, which is a Lean technique, within the Pharmaceutical Supply Chain (PSC). The case study provides insight to the benefits and challenges arising from the application of this technique, within a group of cooperative pharmacists, in Greece. The research questions developed from the review of the literature were tested using evidence from field-based, action research within a pharmaceutical organisation. The reported case study contributes to the longer term debate on assessing the Lean maturity level within the healthcare sector. There are two primary findings: i) that the adoption of kanban system provides a strategic benefit and improves the quality of services. ii) it also provides a basis for a strategy of operational change; it gives the opportunity to the organisation to move away from the current push delivery and logistics systems toward improved logistics strategy models.

Key Words: Lean deployment, Kanban, Healthcare sector

Paper Type: Case Study

1. Introduction

Healthcare provision is generally designed to serve a longstanding role to deliver high-quality services at the point of use. To do this, it requires substantial investments and constant improvement, as it is associated with human life. The proper functioning of these systems result in more patients being adequately taken care of and more lives saved. For this reason, the need for improving the provision of healthcare services with respect to the quality of service, and patient safety and satisfaction is now widely accepted (Institute of Medicine, 2007; Smits *et al*., 2009). However, healthcare organisations have been required to be more effective using the same or similar levels of resource (Cole and Radnor, 2010). Facing this challenge, they are looking for cost saving, waste elimination and better services through implementing innovative programmes such as Lean philosophy (Radnor *et al*., 2012; Radnor, 2010).

Lean thinking was derived from the automobile manufacturing industry and is often described as a method which increases efficiency through the removal of non-value adding activities (Brandao de Souza, 2009; Young and McClean, 2009). Despite the fact that Lean was originated in the industrial sector, over the last decade it has been adopted by other industries, public sector services and healthcare (Bamford *et al*., 2015; Cheng *et al*., 2015 Guthrie, 2006; Lodge and Bamford, 2008; Zhang *et al*., 2012). Moreover, the grey literature reports further evidence of Lean implementation (Brandao de Souza, 2009; Young and McCLean, 2008). However, many researchers characterise Lean implementation in healthcare as patchy and fragmented (Proudlove *et al*., 2008; Young and McCLean, 2008). Bamford *et al*., (2015) suggested that organisations balance 'full' Lean application against the financial costs and operations risks incurred by the intervention. On the other hand, researchers argue that Lean implementation should be aligned to organisational strategy to deliver sustained and continuous service improvement; the adoption of Lean provides a basis for a strategy of operational change (Bamford *et al*., 2015; Ben-Tovim *et al*., 2007; Corbett, 2007; Davies and Walley, 2000; Hines *et al*., 2004; Hines *et al*., 2008).

As detailed above, although numerous articles describe successful Lean implementations in healthcare, there are also many researchers who claim that Lean could further benefit organisations, if the philosophy became part of the organisational culture. Therefore, the authors of this paper were interested in evaluating how Lean is implemented and its potential use within the healthcare sector. To have a better understanding of this phenomenon, a case study related to the pilot implementation of Lean within the Pharmaceutical Supply Chain (PSC) is presented; which examines the benefits arising from the application of the Kanban system, a Lean key technique, within a group of cooperative pharmacists.

This paper is organised as follows: firstly a literature review examines what is already known on this topic; secondly the methodology adopted is explained and justified; thirdly, the case study findings are presented; fourthly, the paper engages in discussion between what was found out and the literature base. Finally, the conclusion makes some recommendations and states areas of interest for future research.

2. The Literature

Lean thinking

Lean is defined as an improvement philosophy that focuses on continual improvement of a process by removing waste, increasing efficiency and providing a higher quality product or service (Brandao de Souza, 2009; Hofer *et al.,* 2011; Young and McClean, 2009). The achievement of this objective requires the determination of waste during the production process (Singh *et al*., 2010). Originating from the Toyota Motor Corporation in Japan, Lean was initially conceived as a radical alternative to the traditional method of mass production and batching principles for maximising operational efficiency, effectiveness, quality, speed and cost (Holweg, 2007). Numerous studies have been done in the past and continue to be made into the development of Lean (Fujimoto, 1999; Hines *et al*., 2004; Holweg, 2007; Ohno, 1988; Womack *et al*., 1990).

Womack and Jones (1996) coined the term 'Lean Thinking' and established Lean's five core principles in order to guide its implementation. These principles are shown in Table 1:

1	Define value desired by the customer
2	Identify the value stream for each product or service
3	Create flow: The product or service should flow continuously
4	Establish pull: The flow should be based on the pull system
5	Pursuit perfection and to eliminate waste

Table 1: Lean's five core principles (Ben-Tovim et al., 2007, Brandao, 2009; Laursen et al., 2003)

The principles of Lean create, by standardising processes, a more controlled environment, improving the management, of the effects of variation in demand (Westwood *et al*., 2006). The implementation of Lean leads to the creation of a 'value' flow at every step, where value tends to be what a customer would pay for and waste represents what a customer would not wish to pay for (Burgess and Radnor, 2013). Therefore, this intervention aims at improving quality by eliminating non-value adding activities. To achieve this objective, numerous tools and techniques can be utilised. Amongst the most popular are work standardisation, value stream mapping, kaizen, 5S, A3 report, PDSA cycles, benchmarking, brainstorming, ABC analysis and Kanban (Burgess and Radnor, 2013). It is worth mentioning that Toussaint and Gerard (2010) suggested a simplification of these principles for healthcare, in order to design care around the patient: identify value for the patient and remove any kind of waste; and minimising time to treatment and throughout its course.

The adoption of Lean by the healthcare sector is regarded as relatively new, considering that Brandao de Souza (2009) identifies the first reference to Lean in UK healthcare in 2001 by the NHS Modernisation Agency. Since then it has been met with apparent great success in healthcare organisations across the world from hospitals in the USA (Savary and Crawford-Mason, 2006), Australia (Bem-Tovim *et al*., 2007) and the UK (Jones and Mitchell, 2006, Fillingham, 2007), in both the acute (Radnor *et al*., 2006; Joosten *et al*., 2009) and community settings (Grove *et al*., 2010a, b). For example, Virginia Mason Medical Centre in Seattle created enough capacity through waste reduction to improve patient safety (Furman & Caplan, 2007); costs and quality were the focus at Thedacare in Wisconsin (Toussaint, 2009) and the service capacity was the driver of Lean in mental health in Denver (LaGanga, 2011). The application of Lean is considered necessary to improve clinical processes for the benefit of patients by increasing quality, safety and efficiency (Fillingham, 2007; Silvester *et al*., 2004; Radnor and Boaden, 2008; Breyfogle and Salveker, 2004).

Holden's (2011) review of Lean applications in Accident and Emergency departments shows that Lean can contribute to decreases in waiting times, length of stay, and the proportion of patients leaving without being seen. Lummus *et al*., (2006) used lean tools in a physician's clinic and significantly improved the patient flow and administrative processes. Similar results have been reported by Kelly *et al*., (2007), in their project, where an emergency department was analysed and redesigned using lean principles. Moreover, research indicates that Lean implementation resulted in reduced lead-time (Al-Araidah *et al*., 2010), clinical errors (Raab *et al*., 2006), inappropriate procedures (Van Lent *et al*., 2009) and enhanced patient and staff satisfaction (Dickson *et al*., 2009).

Although there are numerous reports describing successful Lean implementations in healthcare, literature identifies Lean implementation in healthcare as patchy and fragmented (Balle and Regnier, 2007; Cheng *et al*., 2015; Proudlove *et al*., 2008;Young and McCLean, 2008;). According to Spear (2005, p. 91) *"in healthcare, no organisation has fully institutionalised to Toyota's level, the ability to continuously and systematically eliminate waste"*. In addition to this, researchers argue that a disjointed approach to Lean implementation adversely affects the wider healthcare system (Towill and Christopher, 2005; Waldman and Schargel, 2006). Bamford (2011) and Khurrum *et al*., (2013) point out that Lean is not directly applicable to every single process, its implementation has to be tailored to fit a particular setting and work environment influenced by cultural, methodological and communicational elements (Bamford *et al*., 2015; Inman *et al*., 2011; Losonci *et al*., 2011).

Kanban system

Kanban is a Lean and Just in Time (JIT) technique, which was created to control inventory levels and the production and supply of components (Junior and Filho, 2010). According to Graves *et al*. (1995), kanban is defined as a Material Flow Control mechanism (MFC), which controls the proper quantity and proper time of the production and/or delivery of required products and services. It is a pull system approach that gives authorization to produce at a required rate, in order to control the inventory of product according to customer forecast (Kumar and Panneerselvam, 2007). It utilises visual cards, which provide information to regulate the flow of inventory and materials. Kanban is the Japanese word that refers to the use of these cards (Lin *et al*., 2013). Kanban was created to fulfil specific needs of a company, such as the function of visibility, production control and inventory control (Kouri *et al*., 2008). In particular, its aim is to introduce stability and predictability into inventories, hence being responsive to market changes (Kniberg, 2009).

The application of kanban systems in manufacturing has received much attention with many documented examples of success in improving productivity (Gong *et al*., 2014; Graves *et al*., 1995; Naufal *et al*., 2012; Pettersen and Segerstedt, 2009; Singh *et al*., 2010; Takahashi and Myreshka, 2005). Besides manufacturing, the application of kanban systems has been expanded to other industries, such as software production (Hiranabe, 2008), decision making processes (Gong *et al*., 2014) and knowledge development (Lin *et al*., 2013). The literature reveals that there are major advantages to implementing the kanban system, including: reduction of inventory holding; improvement of material flow; elimination of overproduction; development of visual scheduling and process management; minimisation of obsolete inventory; and improvement of the management of the supply chain (Groos and Mclnnis, 2003; Junior and Filho, 2010; Lin *et al*., 2013).

Lin *et al*., (2013) demonstrate the development of the knowledge kanban system using the concept of kanban management and knowledge engineering technologies. The aim of this application was to provide information to employees regarding relevant knowledge needs to be learnt to support them in executing their activities smoothly and informing them about the knowledge that they need to create, share and revise. As a result, the knowledge kanban system enables smooth knowledge flow, reducing rework and the cycle time hence enhancing efficiency of virtual research and development (R&D) processes. Another representative example is that of BLM Cylinder Head Cover (CHC) manufacturing process, which is a production assembly line that produce cylinder head cover product for Proton model. Naufal *et al*., (2012) describe the application of kanban system in this particular process and conclude that the company achieved excellent improvement in a few areas, such as lead time reduced by 40%; in-process and finished good inventory minimized by 23-29%; and finished goods area optimized by 4%. Similarly, Software Innovation (SI), which is a Scandinavian company, has developed and sold document management products for 28 years, replaced Scrum with Kanban and as a result it almost halved its lead time, reduced the number of weighted bugs by 10% and improved productivity (Johnsen and Solberg, 2012).

Besides the successful implementation of kanban systems, there are relatively few papers describing its variations (Junior and Filho, 2010; Framinan *et al*., 2006; Vernyi and Vinas, 2005). The apparent reason of this focus is the fact that production and market conditions are not the same for all organisations. Therefore, some restrictions have been reported in the literature, such as: kanban is not adequate in situations with unstable demand, non-standardised operations, long setup time and great variety of items (Lin *et al*., 2013; Johnsen and Solberg, 2012; Junior and Filho, 2010). Would this explain why there is weak evidence presenting application of the kanban within the healthcare sector and especially in the PSC?

One of the main reported problems facing the healthcare sector is process inefficiency related to pharmaceutical distribution (Department of Health, 2010). This process inefficiency is caused by the use of very basic but robust logistics and planning systems for pharmaceutical stock control; research strongly suggests that existing systems use only simplistic push logistics (Jamali *et al*., 2010). In addition to this, it is believed that standard logistics strategy models that have been useful to guide managerial policy in other distribution industries are not easily applied to the Pharmaceutical Supply Chain (PSC) (Rosseti *et al*., 2011). The reason for this, is the creation of a web of contingencies, interdependencies, and uncertainties due to the number of consumption points, the role and number of intermediaries, and the long lead times and highly unpredictable nature of bio-pharma manufacturing (Goetschalckx *et al*., 2002). Therefore, an efficient and agile pharmaceutical supply chain is considered essential due to the consistent and strong demand for better drugs to improve the quality of life and for developing a sustainable competitive advantage (Stavrulaki and Davis, 2010; Singh, 2005). As a result, employing a case study approach, the authors sought to explore if the implementation of the kanban systems, a Lean management technique, is able to support the establishment of a defined Pharmaceutical Supply Chain (PSC).

Lean maturity level

A way of assessing the Lean maturity level, a partial or total adoption, is presented by Safayeni's *et al*., (1991) conceptual model, which classifies organisation's efforts towards Lean into four levels, as it is shown in Figure 1.

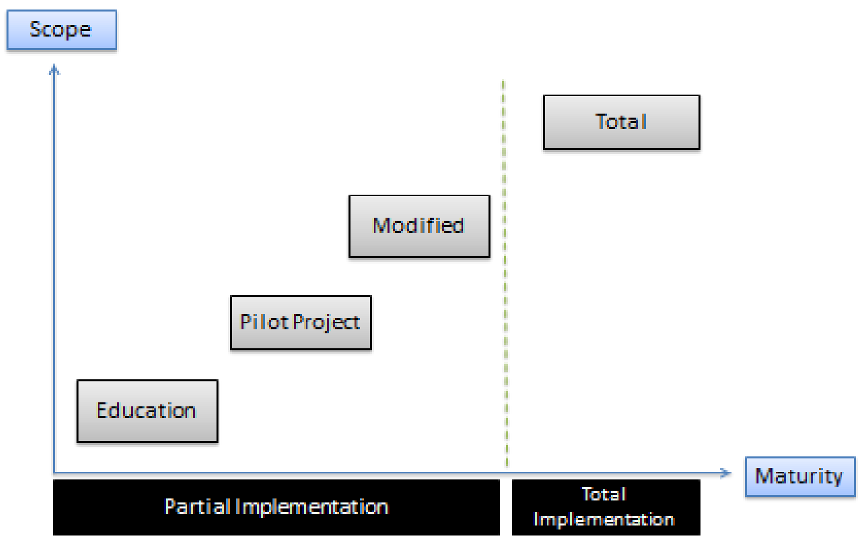

Figure 1: Partial Lean Implementation Model (Safayeni et al., 1991 and Bamford et al., 2015)

Structuring this model, Safayeni's *et al*., (1991) suggested that Lean is applicable at a variety of levels; however great effort is needed in progressing from level to level. In particular, they stated that 'partial implementation may be seen by the management of an organization as a reasonable choice, since it provides an opportunity to explore the ideas of JIT and Lean without changing the overall organisational structure' (Safayeni *et al*., 1991:34). Bamford *et al*., (2015) adopted this model in order to explore the implementation of Lean within two contrasting UK based organisations: a food manufacturer and a healthcare organisation. Their research concludes that partial implementation of Lean does not necessarily represent a conscious organisational choice, but it occurs due to external organisational constraints, such as lack of expertise in deploying improvement programmes.

Despite the fact that the implementation of Lean thinking to healthcare is a recent phenomenon compared to its use in the industrial sector (Fillingham, 2007; Institute for Healthcare Improvement, 2005; Savary and Crawford-Mason, 2006; Jones and Mitchell, 2006), there have been significant interventions in this area. It has been suggested that the healthcare sector is approximately 20 years behind so called 'world class' manufacturing organisations whose staff have a deep understanding about what they should do to remain competitive (Young and McClean, 2009). The transition to Lean requires a significant investment of time, resources and expertise (Womack and Jones, 1996). Most published examples of Lean in healthcare focus on the use of particular tools, such as process mapping, to achieve short-term improvements and there are only a few cases in which Lean interventions are integrated into an organisational-wide strategy (Brandao de Souza, 2009; Mazzocato *et al*., 2010; Radnor *et al*., 2008). Furthermore, it is observed that there are differences in implementing Lean throughout different geographical area; the Japanese for instance have a deeper perceived maturity than their Western counterparts (Tragardh and Lindberg, 2004) explained due to historical and cultural reasons.

Recent studies highlight the need for further research to be undertaken in determining the Lean maturity in healthcare (Arora and Sevdalis, 2010; Arora *et al*., 2010a; Bamford *et al*., 2014; Burgess and Radnor, 2013). Consequently, the objectives of this research are to gain a deeper understanding of this phenomenon and to assess the way Lean has been implemented within healthcare through the kanban application. A group of researchers argue that Lean is applicable at a variety of levels depending on the requirements of the organisation (Mistry, 2005; Papadopoulou and Özbayrak, 2005; Salaheldin 2005); on the other hand, Mazzocato *et al*., (2010), Srinidhi and Tayi, (2004) and Yasin *et al*., (2004) suggest that only a full implementation of Lean can benefit the organisation. Therefore, to explore this area the research focus developed is associated with the impact of a partial Lean implementation upon a healthcare organisation. In particular, the authors were interested in exploring the effectiveness of a Lean technique implementation: kanban, in the Pharmaceutical Supply Chain (PSC). The primary Research Questions (RQ1) = How can a kanban system be implemented, as part of the Lean initiative, to reduce cost and improve efficiency in the PSC? (RQ2) = What are the barriers preventing the supply network to roll out the kanban system? In order to address these questions, a case study approach was chosen. This is outlined and justified in the next section.

3. Research Design and Methodology

This paper investigates the implementation of Lean within the healthcare sector and presents a pharmaceutical supply chain case study describing the application of a pilot kanban system, a Lean technique, within a group of cooperative pharmacists. The case study seeks to assess the contribution of Lean implementation within a healthcare context.

Research methods

To achieve the objectives, this study adopted a case study approach (Yin, 2008). The research question was facilitated by adopting action research where data were gathered from an organisation established by a group of cooperative pharmacists in Greece. As Bryman and Bell (2007) state researchers often struggle to gain access to organisations and collect the required information; however, they deal with this situation through a combination of good opportunity, effective planning and/or hard work. This particular investigation lasted six months during which data was collected through participant observations, reviews of documentation and a schedule of 22 semi-structured interviews with key personnel. These included: procurement specialists, chairman, data managers, logistics managers, technicians and community pharmacists. The aim of this investigation was to examine the current inventory management practices, identify the types of waste associated with the drugs supply chains, as well as to understand the benefits from a pilot kanban implementation. Hence, as a direct result of this research, a kanban system for reducing the waste was recommended.

This study focuses on the PSC and especially on the way that medicines are distributed from a pharmaceutical warehouse to their consumption area. Significant problems are observed during this procedure, which cause delays and unpleasantness to the customers. With a view to overcoming these issues the authors, in conjunction with the organisations, suggested the implementation of a kanban system throughout the supply chain. Specifically, this paper presents the definition and the benefits of a pilot kanban system, followed by a description of the way this technique could be rolled-out within the entire supply chain, established by a group of cooperative pharmacists.

4. Findings

The following section describes the way a pilot kanban system has been designed within a pharmaceutical warehouse and how the extended organisation can benefit from its application. Consequently, the overall aim of the case study is to add to the understanding of wastage in a PSC and to assess how innovative programmes can improve the distribution of medicine.

Case study - The design and use of the kanban system and its benefits in the Pharmaceutical Supply

The organisation founded by a group of cooperative pharmacists has the responsibility for the smooth and regular supply of all types of pharmaceutical and paramedical products to their stakeholders, the community pharmacists, who operate in Greece. The organisation supplies 90% (105) of the pharmacies operating in the same geographical area. It distributes a broad range of products, up to 900 different items (or codes). 80% of these items are predictably stable, which means that their demand is steady over time, the remaining 20% covers those new items entering the market for the first time.

For a better understanding of the environment in which the selected organisation operates, a reference of some general data, related to the country, is necessary. Greece's population amounts to 10,772,967, according to measurements carried out in July 2013. Moreover, the gross domestic product (GDP) or value of all final goods and services produced within the nation in 2012 was $281.4 billion and the total expenditure on healthcare as a percentage of GDP was 13% (2012, est.). It is worth mentioning that the concept of having groups of cooperative pharmacists is strongly developed in Greece; the first of these was established in 1940. Nowadays, 27 groups of cooperative pharmacists operate in Greece, supplying pharmaceuticals and paramedical products to approximately 6,000 associate member pharmacies (www.sofla.gr).

Pharmaceuticals play a vital role in producing healthcare via direct effects on mortality and morbidity (Tetteh, 2009). This fact is associated with the main aim of the organisation, which is to offer an efficient and effective drug delivery. In particular, the challenge that the company has to deal with is the drug availability and medicine access. The cooperative pharmacists have to communicate only with the pharmaceutical warehouse in order to buy the required products, avoiding ordering them through different distribution chains, which would cause problems such as uncertainties and dissatisfied customers. A customer - pharmacist characteristically explained that: *'the warehouse is positioned within the local area, which ensure us an immediate dispatch of the products; we can order and receive the medicines within an hour'*. She continued saying that: *'before creating the cooperative pharmacists' organisation, we had to reach agreement with a number of pharmaceutical companies which made the whole system more complex and occurred frequent delays'*. Obviously, this issue has been shifted to the upstream stage of the delivery process, the warehouse; they have to ensure that the products are available for their customers.

The establishment of this organisation – warehouse has enabled the reduction of acquisition costs through wider short-run spreading of fixed costs, and it has balanced earnings along distribution chains (Tetteh, 2009). Additionally, administrative efficiencies have been realised by promoting the computerization of inventories management (Barber, 2005). More explicitly, they have set up electronic systems in order to increase data availability such as: name and quantity of the available products; prices; and time of delivery. However, this is no guarantee to ensure data quality. One of the associate pharmacists reported that: '*when I order a medicine, the electronic system appears the message: 'out of stock', but when I call the warehouse to double check the availability of this particular medicine, they are able to deliver it to me'*. In contrast to the words cited above, the system administrator exemplified that: *'the main reason for creating the online system was to simplify and improve the communication between the company and the associate pharmacies - our customers; indeed the electronic system is not perfect, but it has enhanced our performance'*.

Regarding the delivery process, the organisation has recruited enough employees in order to be capable to deliver the products on time. The aim is to distribute the medicines within an hour of the ordering time, which means that the pharmacists receive the products five or six times per day. However, it was established that this fact triggered a number of irregularities such as increased paper work – a bureaucratic system. Taking this into account, the organisation decided to set up a number of regulations; for example products can only be delivered free of charge when the order includes drugs that cost more than 50 euros; there is a 5% discount when the online system is used for ordering the required medicines.

Based on the foregoing discussion, the organisation founded by a group of cooperative pharmacists has improved the delivery of medicines, aiming at establishing a robust and efficient pharmaceutical supply chain. As detailed above, the pharmacies benefit by ordering the required products through this warehouse because they can receive the medicines immediately, satisfying their customers. This fact enables them to store fewer items in their store without jeopardising their reputation and reaching agreement with a number of pharmaceutical companies. Although this simplifies and enhances pharmacies' services, more responsibilities have to be undertaken by the warehouse in order to ensure the products availability.

A major problem, which has been observed within the management of the supply chain of medicines, is their short expiry date (Taylor, 2006). In other words, suppliers and users should take into account the expiry date of drugs, because if this date passes, the product will be deemed unusable. For instance, a drug category characterised by a very short self-life includes biotechnology products, such as vaccines. One way to deal with this phenomenon lies in their frequent monitoring and small orders (Schneller and Smeltzer, 2006). However, this policy can lead to their shortage during unexpected demand. For this reason, many pharmaceutical warehouses choose to retain a large inventory of stock (Spear, 2005). This fact causes considerable operational problems in such organisation, for instance, according to Kostagiolas *et al*. (2008) these include: the periodic lack of adequate storage capacity; the expiry of medicinal products, which are stored for a long time; critical drug shortages; purposeless movements of staff in order to find the required drug; and difficulties in staff movements aimed at finding the required drug. An equally important problem is the ill-formed and incomplete orders sent by the pharmacists-members. This results in many other malfunctions such as (Jimmerson *et al*., 2004): increase in the explanatory contacts with customers; delays in the completion of the orders; and unsatisfied customers. Finally, the preparation of the necessary paperwork that accompanies the orders, for example, the purchase and delivery notes, delays the delivery and management of pharmaceutical products (Young *et al*., 2004). Therefore, the operational issues that characterise the organisation demonstrate an opportunity for the implementation of an improved control mechanism, a kanban system, in order to improve the reliability and efficiency of services provided.

Before applying this inventory control system, the 'storage' and 'consumption' area of the products needs to be clarified. The pharmaceutical and paramedical products are stored in the group of cooperative pharmacists' premises and the pharmacists-members' facilities are deemed to be the consuming area. It is worth mentioning that the two-bin kanban system is utilised in order to manage the organisation's inventory. This tool includes two bins of the same size, which are located in the consumption area. The two-bin kanban system helps to simplify product control, by issuing medicines to the pharmacies and 'ignoring' them until the pull signal (an empty bin or kanban card) returns. In other words, when a pharmacist notes that the first bin is empty or a kanban card is displayed, they receive a pull signal and should then send the empty bin to the warehouse to be filled and sent back to the pharmacy.

During this process, the second bin remains in the pharmacy holding enough items to cover the required replacement time. The kanban signal can be digital, which often resulted in better communication between the pharmaceutical companies and the group of cooperative pharmacists and pharmacies; this avoids filling-in a large number of documents and enables employees to focus on improving the quality of services.

An important action during the implementation of an effective two-bin kanban system is to identify which products are candidates for a two-bin kanban system (small and inexpensive components) and which are valuable enough to merit significant management attention. A straightforward way was to sort the products by the highest revenue, using the classic Pareto or ABC classification method (Bamford and Forrester, 2010). This method divides the product collection in three categories, basing its ratings on the following rules: i) the first group (A) is often a small amount of products which generate the largest part of the revenue. In particular, the top 75-80% of the annual consumption value of the organisation accounts for only 15-20% of total inventory products; ii) The second group (B) contains the interclass products, with a medium consumption value; 20-25% of the annual consumption value accounts for 20-25% of total inventory products; iii) The third group (C) includes the products with the lowest consumption value; 10-15% of the annual consumption value accounts for 60-65% of total inventory products. In order to identify which products are candidates for a two-bin kanban system; the combination of ABC method with the demand of products is required. In Table 1, the horizontal axis refers to the value of the products. The category A includes the expensive products, category B the products with a medium value and category C characterises the cheaper ones. The vertical axis refers to the demand profile. Category X corresponds to steady demand, Y to mild and Z to casual one. Table 2 shows the products managed by the group of cooperative pharmacists that are candidates for kanban system.

Category		**A**		**B**		**C**		**Total**			
		Value	Part No	Value	Part No	Value	Part No	Value	Part No	Value %	Part No%
X	KANBAN	14,752,937	290	2,120,365	376	470,400	768	17,343,701	1,434	44.1%	25.4%
Y		8,636,265	186	1,893,859	340	618,718	1,111	11,148,842	1,637	28.4%	29%
Z		4,084,188	80	836,758	154	310,017	684	5,230,963	918	13.3%	16.3%
	No	4,034,660	120	99,438	185	536,561	1,364	5,564,659	1,651	14.2%	29.3%
Total	Value	31,508,050	658	5,844,419	1,055	1,935,696	3,927	36,288,165	5,640	100%	
	%	80.2%	11.7%	14.7%	18.7%	4.9%	69.6%	100%			

Table 2: ABC classification for the group of cooperative pharmacists' products

From Table 1, it can be concluded that a large percentage, 70.7% of the products managed by the cooperative, are candidates for kanban system. This suggests that the organisation can eliminate the waste of time and cost, increase the quality of its services, and meet their customers' needs, by applying the system.

The next step for implementing the kanban system is the calculation of the storage 'bin' size. In other words, in order for the kanban system to work properly the product quantity contained in each bin should be calculated. The kanban quantities of the products managed by the company and participating in the kanban system needs to be determined, taking into account the proposed and agreed inventory policy. In particular, the inventory policy suggested to the organisation in order to manage its products properly (avoiding lengthy inventory processes, eliminating waste and the risk of damaging items, and meeting the customers' needs) was:

- Products belonging to category A will be maintained in the warehouse for 4 days.
- Products belonging to category B will be maintained in the warehouse for 10 days.
- Products belonging to category C will be maintained in the warehouse for 30 days.

The following Table 3 represents the kanban quantities and shows the total number of products which have to be stocked. In order for the organisation to be able to satisfy their customers, whilst eliminating wastes in terms of time and cost, 671.225 items need to be held at a value of 4.189.393,22€.

Category		**A**		**B**		**C**		**Total**	
		Value	Kanban	Value	Kanban	Value	Kanban	Value	Kanban
X	KANBAN	1,161,406	89,127	455,216	92,523	343,029	114,278	1,959,651	295,928
Y	KANBAN	675,123	57,745	395,797	64,954	444,964	142,936	1,515,885	265,635
Z	KANBAN	321,431	20,092	167,699	27,694	224,728	61,876	713,858	109,662
Z	No	0	0	0	0	0	0	0	0
Total	Value	2,157,961	166,964	1,018,712	185,171	1,012,721	319,090	4,189,393	671,225

Table 3: Quantity and value of products needed to be stored in the warehouse

It is worth noting that the organisation's inventory policy before this pilot implementation of the kanban system was 22 days for all products categories. According to this policy, the warehouse has to store 1.555.910 items whose value is 14.838.287, 30€. The following table compares the current inventory policy with the proposed one. It is concluded that if the organisation adopts and fully roll-out this proposed policy, it will store 56.8% fewer products and reduce the cost by 71.8%, as illustrated by Table 4.

	Inventory Policy			
	22 days	4 ds, c.A/10 ds, c.B/30 ds, c.C	**Difference**	**Difference %**
Kanban	1,555,910	67,225	884,685	56.8
Value	14,838,287.30	4,189,393.22	10,648,894.08	71.8

Table 4: A comparison between the current and the proposed inventory policy

As a result, it is obvious that the implementation of the kanban system can impact positively upon the operation of the pharmaceutical warehouse; however, the organisation did not fully proceed to the actual application of kanban. The reason for this, which derived via the interviews with key personnel, was that the personnel were not familiar enough with this technique and therefore the employees did not feel ready to change their way of working which rely on their experience. Bamford *et al*., (2015) assume that the adoption of specific tools and techniques by organisations is dependent on the organisations' characteristics such as: type of waste which has to be addressed; needs and demands of patients and employees; or functional rules due to the different legal context. Although some employees were keen to contribute and fully implement this system, the majority of them were worried about the potential risk and the disruption caused by the application of kanban. In particular, their main concerns were related to their lack of expertise in deploying improvement programmes, the shortage of the required medicines and the key suppliers' failure to reliably deliver on time, quality and quantity (Chairman, interviews conducted in 2010). However, one could wonder whether these issues can be addressed with further specific training or if more structural changes within the culture of the organisation have to occur?

Womack and Jones (1996) indicate that the transition to Lean requires a significant investment of time, resources and expertise. In addition to this, a logistics manager (2010) highlighted the high complexity characterised the Pharmaceutical Supply Chain; the planning and design of it needs to consider the political and legal constraints such as the guidelines from the National Organisation for Medicines (www.eof.gr). There are some types of medicines that might only be used once a year - but they have to be kept (just in case). Finally, another challenge, that the organisation would face, if the full kanban implementation was occurring, is the stakeholders' engagement. Frohlich and Westbrook (2001) and Ryals et al. (2010) report that the process of formulating and implementing innovative programmes should link with the wider supply chain to increase the so-called 'arc of integration' to avoid sub-optimisation down the supply network.

Despite these issues, the kanban framework developed for this pilot project became an opportunity for the organisation to create structure and manage changes and improvement, hence being familiar with innovative programmes. The pilot implementation of kanban was based on real data rather than theoretical prescriptions deriving from the literature. This was important for both the organisation and researchers, because they had the chance to evaluate the impact of the kanban application upon the organisation's performance. The authors suggest that a partial lean implementation, through the application of kanban, could enhance the planning and design of medicines delivery, by improving the efficiency and the effectiveness to satisfy the local demand. Despite the fact that some experts and researches argue that only a full implementation of Lean can benefit the organisation (Yasin *et al*., 2004; Mazzocato *et al*., 2010).

5. Discussion

In order to provide clear structure for the discussion and achieve the research objectives, this section has been arranged around the developed research questions. In addition to the potential that the pilot application of the kanban system leads to a reduction of waste in terms of time and cost, the organisation can also reassess, implement and adjust this Lean tool to suit its own needs, because the application process is reasonably simple and does not require specialised equipment or knowledge (Gong *et al*., 2014; Naufal *et al*., 2012). Accurate stock figures and the agreement and cooperation of the stakeholders involved in the supply chain is required, and whilst it is sometimes difficult and time consuming to develop these levels of agreement (Sanchez-Rodrigues *et al*., 2010; Junior and Filho, 2010; Johnsen and Solberg, 2012), the potential exists. As detailed above, the implementation of a kanban system should create a continuous flow during the production process (Junior and Filho, 2010; Burgess and Radnor, 2013). Hence, the departments of the cooperative are interdependent and will therefore become more responsible because their work affects their perceived colleagues' work. Moreover, the enhanced communication between the partners within the supply chain has the potential to create a friendlier working environment (Lin et al., 2013; Junior and Filho, 2010).

Within this research paper it was established that the application of a kanban system can benefit an organisation and improve the quality of services. More explicitly, the application of this technique, by implementing Lean thinking, can help the pharmacists to achieve a more reliable product flow in their supply chain and eliminate delays and 'waste' during the process. The outputs of the case study reveal that the organisation could store 56.8% fewer products and save 71.8% in storage costs by adopting the kanban system. These results address the first research question related to the impact of the kanban system implementation within the PSC. This technique is capable of being adopted and it does not require specialised equipment. However, there are some perceived risks which must be addressed such as the potential risk of medicines shortage caused mainly by external factors such as the key suppliers not to adopt the Just in Time (JIT) technique, failing to deliver the required items on time and in high quality. In particular, as some drug categories characterised by a short self-life (biotechnology products) there is the risk of stock out and especially during unexpected demand. Literature reveals that kanban is not adequate in situations with unstable demand and non-standardised operations (Lin *et al*., 2013; Johnsen and Solberg, 2012; Junior and Filho, 2010).

By applying kanban, rapid and accurate usage information can be gathered, which means that the organisation knows at any time the quantity and type of products which are available in the warehouse. In addition, the customers' service is prompt and efficient as the organisation knows the customer needs and satisfies them automatically without the use of orders and other similar documents. The ability to predict provides the ability to control (Ding *et al*., 2014). As a result, the application of a kanban system presents an opportunity for the pharmaceutical industry to move away from the current push delivery and logistics systems (Jamali *et al*., 2010) towards improved logistics strategy models.

Interestingly, after the introduction of the pilot kanban project, the employees were very positive and appreciated the results. A technician characteristically said: *'we could not imagine that a better management of our stock could save this amount of money'*. However, this tool has never been fully deployed through the organisation. The reasons are analysed in this section and address the second question related to the barriers preventing the supply network to roll out the kanban system. One of the main reasons of not adopting this technique might be the fact that they had to change their way of working and also influence their stakeholders' strategy. To quote the logistics manager: *'in my understanding, in order to implement this improvement tool successfully, we have to cooperate with our stakeholder and persuade them to adopt the new system; it seems to me really difficult to influence all of the 105 community pharmacies'*. He continued saying that *'the other issue is that the application of the kanban system could improve our efficiency, but there is not an example of implementing it within a similar organisation in our country, so I do not think that we are ready to take this risk'*. Therefore, another reason of not applying the kanban system is that they might fear to implement a new and innovative technique because they felt unprepared to take this risk and cope with a potential failure (Ghadge *et al.,* 2012). In addition to this, there are some external factors that hinder the adoption of specific tools by organisations, such as demands of customers and functional rules due to a particular legal context; the delivery of medicines is depended on the guidelines from the National Organisation for Medicines. For example, the inventory manager highlighted that: *'according to the national guidelines, some lines/types of medicines have to be kept (just in case); they might only be used once a year. This means that we cannot operate interpedently – we cannot fully control our storage'*.

The successful implementation of kanban system requires the participation of all stakeholders involved in the supply chain. Therefore, when organisations and especially pharmaceutical organisations decide to apply and adopt the kanban system or a similar Lean programme, it has to support it and change its strategy accordingly to avoid sub-optimisation. In addition to this, the company should share the benefits derived by innovative programmes with their suppliers and customers in order to persuade them to apply these programmes in their organisation (Fawcett *et al*., 2010). If all stakeholders involved in a supply chain adhere to the same policy, then the benefits of innovative programmes will be greater and also their relationship will improve.

From the authors' interpretation and the comparison between the literature and the case study outputs, it can be established that the Lean implementation, through the pilot implementation of kanban, within this organisation can be classified at the education level of the Safayeni et al.'s (1991) maturity model. Although the case study describes and assessed a Lean implementation at the education level of the maturity model, it concludes that the application of kanban system minimises the waste in time, products, storage space and reduce the cost. In addition to this, it creates greater flexibility with smaller runs and makes supply more reliable with less need to rely on inventory (Bamford *et al*., 2014). Therefore, even a partial Lean implementation or the intention of applying Lean can benefit the organisation (Hines et al., 2008; Bamford et al., 2014). However, an integrated adoption of Lean programmes would result in much improved services (Inman et al., 2011; Losonci et al., 2011).

6. Conclusion

This paper has evaluated Lean implementation and its potential in the healthcare sector. To achieve the objective, a review of Lean philosophy literature was conducted and a case study related to the implementation of kanban system within the Pharmaceutical Supply Chain (PSC) was presented. The case study is offered to communicate the benefits arising from the pilot application of a kanban system, a Lean technique, within an organisation founded by a group of cooperative pharmacists. In addition to this, a better understanding of the reasons preventing the Pharmaceutical Supply Chain to adopt this technique was achieved.

The case study presentation demonstrates that the application of a kanban system can impact positively upon the operations of an organisation; however there are some stochastic supply problems that need to be overcome such as the logistic information systems. Besides the issues related to the delivery of medicines, there are also those which are associated with the organisational culture. It is believed that one of the main problems facing the healthcare sector is process inefficiency related to pharmaceutical distribution (Department of Health, 2010). The reason for this may be the use of basic but robust logistics and planning systems for pharmaceutical stock control. Therefore, the implementation of this Lean process improvement technique is an opportunity for the pharmaceutical industry to move away from the current push delivery and logistics systems, improving the quality of required services hence reducing the cost. In order for this to be achieved, an extensive application of Lean within the stakeholders is essential. Although this particular company can benefit from implementing kanban, this Lean technique needs to be applied within the upstream and downstream stages of the pharmaceutical supply chain, in order to be fully effective. Alternatively, they can revel in the status quo, which might have an impact upon the healthcare organisations' efficiency and people's health and well-being.

The actual kanban implementation will be slow and difficult, considering the changes and uncertainties that might arise. For this reason, the organisation founded by a group of cooperative pharmacists can take the initiative to apply this technique and share its experience and the benefits deriving from it with the stakeholders to convince of adapting it within their company. The first step for creating reliable drug supply chains to ensure continuous provision of affordable is the communication between the different stages of the supply chain. Drummond-Hay and Bamford (2009) suggest that successful improvements are subjected to an agreement that everyone within an organisation should work in one direction.

Subsequently, the application of Lean could be easier and conscious, resulting in a number of benefits.

In particular, the application process is simple and does not require specialised equipment or knowledge; as a result the kanban system can be implemented and adjusted to meet the organisations' needs. Rapid and accurate data can be achieved, avoiding the issues reported by the interviewees regarding incorrect information. Finally, the quality of services can be improved, hence minimising waste and costs.

The Lean approach continues to attract a great deal of interest as an improvement approach in healthcare (Cheng et al., 2015; Lodge and Bamford, 2008; Smits et al., 2009; LaGanga, 2011; Radnor *et al*., 2012; Zhang *et al*., 2012), but further research is required in order that its feasibility and effectiveness is fully understood (Young *et al*., 2008). It is considered essential that the implementation of Lean is a long term, strategic programme and not a short term fix (Bale *et al*., 2007) and requires a certain commitment from the senior leaders. Spending as much time as is required, and committing the correct resources are prerequisites for a successful intervention. However, knowing how long this should take and how much resource to commit remains rather elusive.

The case study reveals that the described Lean implementation belongs to the education level according the classification of Safayeni *et al*., (1991). Taking into account the case study and the outputs of the literature review, the authors also suggest that the way of applying Lean, is environmentally dependent (Bamford, 2011; Khurrum *et al*., 2013; Inman *et al*., 2011; Losonci *et al*., 2011), as this research was conducted in Greece, the generalisation of findings are limited, and further research in different geographical areas are relevant area for future research. The literature reveals that different geographical areas use diverse improvement tools in order to achieve their objectives. The authors assume that there are reasons leading to the adoption of specific tools by organisations, such as: the different type of waste which has to be addressed; different needs and demands of patients and employees; different functional rules due to the different legal context; or may be the preference of the management team for some improvement tools, because it is familiar with them and knows how to use them effectively.

References

Al-Araidah, O., Momani, A., Khasawneh, M. and Momani, M. (2010) "Lead-time reduction utilizing lean tools applied to healthcare: the inpatient pharmacy at a local hospital", Journal for Healthcare Quality, Vol. 32, No. 1, pp.59–66.

Balle, M. and Regnier, A. (2007), "Lean as a learning system in a hospital ward", Leadership in Health Services, Vol 20, No 1, pp 33-41.

Bamford, D. and Forrester, P. (2010), Essential Guide to Operations Management, Wiley

Bamford, D., (2011) "The Lean Leadership Paradigm", Session at Lean Management Journal Annual Conference, June 2011, Birmingham.

Bamford, D., Forrester, P., Dehe, B. and Leese, R., (2015) "Partial and Iterative Lean Implementation: Two Case Studies", International Journal of Operations and Production Management

Barber, N. (2005). Regulating Pharmaceuticals in Europe: Striving for Efficiency, Equity and Quality. Quality And Safety In Health Care, 14(3), 227-228. doi:10.1136/qshc.2004.012070

Bem-Tovim, D., Bassham, J., Bolch, D., Martin, M.A., Dougherty, M. and Szwarcbord, M. (2007), "Lean thinking across a hospital: redesigning care at the Flinders Medical Centre", Australian Health Review, Vol. 31, pp. 10-15.

Brandao de Souza, L. (2009), "Trends and approaches in lean healthcare", Leadership in Health Services, Vol. 22 No. 2, pp. 121-39

Breyfogle, F., Salveker, A., (2004) "Lean Six Sigma in Sickness and in Health", Smarter Solutions, Austin, TX.

Bryman, A. and Bell, E., (2007), Business Research Methods, Oxford University Press, Oxford

Burgess, N. and Radnor, Z., (2013), "Evaluating Lean in healthcare", International Journal of Health Care Quality Assurance, Vol. 26, No. 3, pp. 220-235.

Cheng, S., Bamford, D., Papalexi, M. and Dehe, B. (2015) 'Improving access to health services – Challenges in Lean application' International Journal of Public Sector Management. ISSN 0951-3558

Cole, J. and Radnor, Z. (2010), "How healthy is the annual health check?", International Journal of Health Care Quality Assurance, Vol. 23 No. 6, pp. 537-53.

Corbett, S. (2007), "Beyond manufacturing: the evolution of lean production", The McKinsey Quarterly, Vol. 3, pp. 95-105.

Davies, C.L. and Walley, P. (2000), "Clinical governance and operations management methodologies", International Journal of Health Care Quality Assurance, Vol. 13 No. 1, pp. 21-6.

Department of Health (DoH), (2010), "New study on medicine waste", available at: http://www.dh.gov.uk/en/Aboutus/Features/DH_122051 (accessed 20th March 2011).

Dickson, E. W., Anguelov, Z., Vetterick, D., Eller, A. and Singh, S., (2009), "Use of Lean in the Emergency Department: A Case Series of 4 Hospitals", Annals of Emergency Medicine, 54, 504 - 510.

Dickson, E., Singh, S., Cheung, D., Wyatt, C. and Nugent, A, (2009), 'Application of Lean manufacturing techniques in the emergency department', The Journal of Emergency Medicine, Vol. 37, pp.177–182.

Ding, M.J., Ferry Jie, F., Kevin A. Parton, K.A. and Matanda, M.J. (2014) "Relationships between quality of information sharing and supply chain food quality in the Australian beef processing industry", The International Journal of Logistics Management, Vol. 25 No. 1, pp.85 - 108

Drummond-Hay, R. and David Bamford, D., (2009), 'A case study into planning and change management within the UK National Health Service', International Journal of Public Sector Management, Vol. 22, No. 4, pp. 324-337

Fawcett, S.E., Waller, M.A. and Fawcett, A.M. (2010) "Elaborating a dynamic systems theory to understand collaborative inventory successes and failures", The International Journal of Logistics Management, Vol. 21, No. 3, pp.510 - 537

Fillingham, D. (2007), "Can Lean save lives?", Leadership in Health Services, Vol. 20 No. 4, pp. 231-241.

Framinan, J.M., Gonzalez, P.L. and Ruiz-Usano, R., (2006), "Dynamic card controlling in a

CONWIP system", International Journal of Production Economics, Vol.99, pp.102–116.
Frohlich, M.T., Dixon, J.D., (2001), "A taxonomy of manufacturing strategies revisited", Journal of Operations Management, Vol.19, pp.541-558.
Fujimoto, T. (1999). "Organisational for effective product development - The case of the global automobile industry", Boston: Harvard University Graduate School of Business Administration.
Furman, C. and Caplan, R. (2007), "Applying the Toyota Production System: Using a Patient Safety Alert System to Reduce Error", The Joint Commission Journal on Quality and Patient Safety, Vol.33, No.7, pp.376-386.
Ghadge, A., Dani, S. and Kalawsky, R. (2012) "Supply chain risk management: present and future scope", The International Journal of Logistics Management, Vol. 23, No. 3, pp.313 - 339
Goetschalckx, M., Vidal, C.J. and Dogan, K. (2002), "Modeling and design of global logistics systems: a review of integrated strategic and tactical models and design algorithms", European Journal of Operational Research, Vol. 143 No. 1, pp. 1-18.
Gong, Q, Yang, Y. and Wang, S., (2014), "Information and decision-making delays in MRP, KANBAN, and CONWIP", International Journal Production Economics, Vol. 156, pp.208-213.
Groos, J.M. and Mclnnis, K.R., (2003), "Kanban made simple: demystifying and applying Toyota's legendary manufacturing process", United States of America: AMA-COM.
Grove, A.L., Meredith, J.O., Macintyre, M., Angelis, J. and Neailey, K. (2010a) "Challenges faced by a UK health visiting service during lean implementation", Leadersh Health Serv Vol. 23, pp.204–218.
Grove, A.L., Meredith, J.O., Macintyre, M., Angelis, J., Neailey, K. (2010b) "Lean implementation in primary care health visiting services in National Health Service UK", Quality and Safety in Health Care.
Guthrie, J. (2006), "The Joys of a Health Service Driven by Toyota", Financial Times
Hines, P., Found, P. and Harrison, R. (2008), "Staying Lean: Thriving, Not Just Surviving, 1st ed., Lean Enterprise Research Centre", Cardiff University, Cardiff.
Hines, P., Holweg, M. and Rich, N. (2004), "Learning to evolve: a review of contemporary Lean Thinking", International Journal of Operations & Production Management, Vol. 24 No. 10, pp. 994-1011.
Hiranabe, K., (2008), "Kanban applied to software development: from agile to lean", http://www.infoq.com/articles/hiranabe-lean-agile-kanban
Hofer, A.R., Hofer, C., Eroglu, C. and Waller, M.A. (2011) "An institutional theoretic perspective on forces driving adoption of lean production globally : China vis-à-vis the USA", The International Journal of Logistics Management, Vol. 22 Iss: 2, pp.148 - 178
Holden RJ, (2011), "Lean Thinking in emergency departments: a critical review", Annals of emergency medicine, Vol.57, No.3, pp.265-278.
Holweg, M. (2007), "The genealogy of lean production", Journal of Operations Management, Vol.25, pp.420-437.
Inman, R. A., Sale, R. S., Green Jr, K. W. and Whitten, D. (2011). "Agile manufacturing: relation to JIT, operational performance and firm performance." Journal of Operations Management, Vol.29, No.4, pp.343-355

Institute for Healthcare Improvement, (2005), “Going Lean in Health Care. Innovation Series 7”, Cambridge, MA: Institute for Healthcare Improvement.
Institute of Medicine, (2007), “Hospital-Based Emergency Care: At the Breaking Point”, Washington, DC: National Academies Press.
Jamali, D., Hallal, M. and Abdallah, H. (2010). “Corporate governance and corporate social responsibility: evidence from the healthcare sector”. Corporate Governance, vol. 10, No. 5, pp. 590-602
Jimmerson, C., Weber, D., Sobek, D., (2004), “Piloting Waste and Errors: Piloting Lean Principles at IHC”, Joint Commission Journal on Quality and Safety.
Johnsen, A. and Solberg, J., (2012), “Quantifying the Effect of Using Kanban versus Scrum: A Case Study” IEEE Software.
Jones, D. and Mitchell, A. (2006), “Lean Thinking for the NHS”, NHS Confederation, London.
Joosten T, Bongers I, Janssen R (2009), “Application of lean thinking to health care: issues and observations”, Int J Qual Health Care Vol.21, No.341–347.
Junior, M.L. and Filho, M.G., (2010), “Variations of the kanban system: Literature review and classification”, International Journal Production Economics, Vol.125, pp. 13–21.
Kelly, A., Bryant, M., Cox, L. and Jolley, D. (2007) “Improving emergency department efficiency by patient streaming to outcomes-based teams”, Australian Health Review, Vol. 31, No. 1, pp.16–21.
Khurrum, M., Bhutta, S., Rosado–Feger, A.L., Huq, F. and Muzaffar, M. (2013), “Exploratory study of adoption of lean management practices in Pakistani textile firms”, International Journal of Services and Operations Management, Vol.15, Iss.3, pp.338-357
Kniberg, H., (2009), “Kanban vs. scrum - how to make the most of both”, http://www.crisp.se/henrik.kniberg/Kanban-vs-Scrum.pdf
Kostagiolas, P., Kaitelidou, D., Hatzopoulou, M., (2008), “Improving the quality of health services”, Papasotiriou, Athens
Kouri, I.A., Salmimaa T.J, and Vilpola, I.H., (2008), “Novel algorithms and techniques in telecommunication, automation and industrial electronics”, Science Business Media, Berlin: Springer, pp.99–104.
Kumar, C.S. and Panneerselvam, R., (2007), “Literature review of JIT-KANBAN system”, The International Journal of Advanced Manufacturing Technology, Vol.32, pp.393-408.
LaGanga, L.R. (2011), “Lean service operations: Reflections and new directions for capacity expansion in outpatient clinics”, Journal of Operations Management, Vol.29, No.5, pp. 422-433
Laursen, M., Gertsen, F., and Johanson, J., (2003), “Applying lean thinking in hospitals—exploring implementation difficulties”, Center for Industrial Production: Denmark.
Lin, C.J., Chen, F.F. and Chen, Y.M., (2013), “Knowledge kanban system for virtual research and development”, Robotics and Computer-Integrated Manufacturing, Vol. 29, pp. 119-134.
Lodge, A., Bamford, D. (2008), “Using Lean techniques in radiology waiting time improvement: a case study”, Public money and management, Vol.28, ISS.1,pp.49-52.
Losonci, D., Demeter, K. and Jenei, I., (2011), “Factors influencing employee perceptions in

lean transformations", International Journal of Production Economics, Vol.131, pp.30-43.
Lummus, R.R., Vokurka, R.J. and Rodeghiero, B. (2006) "Improving quality through value stream mapping: a case study of a physicians clinic", Total Quality Management & Business Excellence, Vol. 17, No. 8, pp.1063–1975.
Mazzocato P, Savage C, Brommels M, Aronsson Hk, Thor J, (2010), "Lean thinking in healthcare, a realist review of the literature", Quality & safety in health care, Vol.19, No.5, pp.376-382.
Mistry, J.J., (2005), "Origins of profitability through JIT processes in the supply chain", Industrial Management & Data Systems, Vol.105, No.6, pp.752-768.
Naufal, A., Jaffar, A., Yusoff, N and Hayati, N., (2012), "Development of Kanban System at Local Manufacturing Company in Malaysia – Case Study", Procedia Engineering, Vol. 41, pp. 1721 – 1726.
Ohno, T. (1988), "The Toyota production system: Beyond large-scale production", Portland: Productivity Press.
Papadopoulou, T.C., Özbayrak, M., (2005), "Leanness: experiences from the journey to date", Journal of Manufacturing Technology Management, Vol.16, No.7, pp. 784-807.
Pettersen, J. and Segerstedt, A., (2009), "Restricted work-in-process: a study of differences between KANBAN and CONWIP", International Journal Production Economics, Vol.118, No.1, pp.199–207.
Proudlove, N., Moxham, C. and Boaden, R. (2008), "Lessons for Lean in healthcare from using six sigma in the NHS", Public Money and Management, Vol. 28 No. 1, pp. 27-34.
Raab, S.S., Andrew-JaJa, C., Condel, J. and Dabbs, D., (2006), "Improving Papanicolaou test quality and reducing medical errors by using Toyota production system methods", American Journal of Obstetrics and Gynecology, Vol. 194, pp.57–64.
Radnor Z, Walley P, (2008), "Learning to walk before we try to run: Adapting Lean for the public sector", Public Money & Management, Vol.28, No.1, pp.13-20.
Radnor Z, Walley P, Stephens A, Bucci G (2006), "Evaluation of the lean approach to business management and its use in the public sector (summary report)", Research Findings No.20/2006, Scottish Executive, Office of Chief Researcher, Edinburgh.
Radnor, Z. (2010), "Literature Review of Business Process Improvement Methodologies", Advanced Institute of Management Research, London.
Radnor, Z. and Boaden, R. (2008), "Editorial: Lean in the public services: panacea or paradox?", Public Money and Management, Vol. 28 No. 1, pp. 3-6.
Radnor, Z.J., Holweg, M. and Waring, J. (2012), "Lean in healthcare: the unfilled promise?", Social Science & Medicine, Vol. 74 No. 3, pp. 364-71.
Rossetti, C., Handfield, R., Dooley, K., (2011), "Forces, trends, and decisions in pharmaceutical supply chain management", International Journal of Physical Distribution & Logistics Management, Vol. 41, No. 6, pp. 601-622.
Ryals, L.J. and Humphries, A.S. (2010) "Efficiency versus value maximisation in co-manufacturing relationships", The International Journal of Logistics Management, Vol. 21 Iss: 2, pp.309 - 330
Safayeni, F., Purdy, L., Van Engelen, R. and Pal, S., (1991), "Difficulties of Just-in-Time Implementation: A Classification Scheme", International Journal of Operations &

Production Management, Vol.11, No. 7, pp.27-36.

Salaheldin, S.I., (2005), "JIT implementation in Egyptian manufacturing firms: some empirical evidence", International Journal of Operations & Production Management, Vol.25, No.4, pp.354-370.

Sanchez-Rodrigues, V., Potter, A. and Naim, M.M. (2010) "Evaluating the causes of uncertainty in logistics operations", The International Journal of Logistics Management, Vol. 21 Iss: 1, pp.45 - 64

Savary, L. and Crawford-Mason, C, (2006), "The Nun and the Bureaucrat: How they Found an Unlikely Cure for America's Sick Hospitals", CC-M Productions, Washington, DC.

Schneller, E. and Smeltzer L., (2006), "Strategic Management of the Health Care Supply Chain", Jossey-bass.

Silvester, K., Lendon, R., Bevan, H., Steyn, R. and Walley, P. (2004), "Reducing waiting times in the NHS: is lack of capacity the problem?", Clinician in Management, Vol. 12 No. 3, pp. 105-11.

Singh B, Garg S, Sharma S, Grewal C, (2010), "Lean implementation and its benefits to production industry", Int J Lean Six Sig, 1(2):157–168.

Singh, B., Garg, S.K., Sharma, S.K. and Grewal, C., (2010), "Lean implementation and its benefits to production industry". International Journal of Lean Six Sigma, Vol.1, No.2, pp.157-168.

Singh, M., (2005), "The Pharmaceutical Supply Chain: a Diagnosis of the State-of-the-Art2, Massachusetts Institute of Technology.

Smits M, Groenewegen PP, Timmermans DRM, (2010), "The nature and causes of unintended events reported at ten emergency departments", BMC Emerg Med. 2009;9. Available at: http:// www.biomedcentral.com/1471-227X/9/16. Accessed September 22.

Spear, S.J. (2005), "Fixing health care from the inside", Harvard Business Review, Vol. 83 11, September, pp. 78-91.

Srinidhi, B., Tayi, G.K., (2004), "Just in time or just in case? An explanatory model with informational and incentive effects", Journal of Manufacturing Technology Management, Vol.15, No.7, pp.567-574.

Stavrulaki, E. and Davis, M. (2010) "Aligning products with supply chain processes and strategy", The International Journal of Logistics Management, Vol. 21 No. 1, pp.127 - 151

Takahashi, K. and Myreshka, H.D., (2005), "Comparing CONWIP, synchronized CONWIP, and KANBAN in complex supply chains", International Journal Production Economics, Vol.93-94, pp.25–40.

Taylor, D., (2006), "Supply Chain Management", Kleidarithmos, Athens.

Tetteh, E. (2009). Creating reliable pharmaceutical distribution networks and supply chains in African countries: Implications for access to medicines. Research In Social And Administrative Pharmacy, 5(3), 286-297. doi:10.1016/j.sapharm.2008.08.001

Toussaint, J. (2009), "Writing The New Playbook For U.S Health Care: Lessons From Wisconsin", Health Affairs, Vol.28, No.5, pp.1343-1350.

Toussaint, J. and Gerard, R., (2010), "On the Mend", Lean Enterprise Institute, Cambridge, MA.

Towill, D. and Christopher, M. (2005), "An evolutionary approach to the architecture of effective healthcare delivery systems", Journal of Health Organisation Management, Vol.

19 No. 2, pp. 130-47.
Tragardh, B. and Lindberg, K., (2004), “Curing a meager health care system by lean methods—translating chains of care in the swedish health care sector”, International Journal of Health Planning and Management, Vol.19, No.4, pp.383–398.
Van Lent, W., Goedbloed, N. and Van Harten, W., (2009), “Improving the efficiency of a chemotherapy unit: applying a business approach to oncology”, European Journal of Cancer, Vol. 45, pp.800–806.
Vernyi, B. and Vinas,T., (2005), “Easing into e-kanban”, Industry Week, Vol.254, No.12, pp.32.
Waldman, J.D. and Schargel, F.P. (2006), “Twins in Trouble II: systems thinking in healthcare and education”, Total Quality Management, Vol. 17, pp. 117-30.
Westwood, N., James-Moore, M. and Cook, M., (2006), “Going lean in the NHS”, NHSI, NIfIaI, London.
Womack, J. and Jones, D., (1996), “Lean Thinking”, Simon & Schuster, New York, NY.
Womack, J. P., Jones, D. T., & Roos, D., (1990), “The machine that changed the world”, New York: Rawson Associates.
Yasin, M.M., Wafa, M., Small, M.H., (2004), “Benchmarking JIT: An analysis of JIT implementations in the manufacturing service and public sectors”, Benchmarking: An International Journal, Vol.11, No.1, pp.74-92.
Yin, R.K., (2008), “Case Study Research: Design and Methods”, SAGE Publications London.
Young, T. and McCLean, S. (2008), “A critical look at Lean Thinking in healthcare”, Quality and Safety in Health Care, Vol. 17, pp. 382-6.
Young, T. and McClean, S. (2009), “Some challenges facing lean thinking in healthcare”, International Journal of Quality in Health Care, Vol. 5, pp. 309-10.
Young, T., Brailsford, S., Connell, C. and Davies, R., (2004), “Using industrial processes to improve patient care”, British Medical Journal.
Zhang, Z., Bamford, D., Moxham, C. and Dehe, B. (2012) ‘Strategy Deployment Systems within the UK Healthcare Sector: A Case Study’ International Journal of Productivity and Performance Management , 61 (8), pp. 863-880. ISSN 1741-0401